

The Effects of Fiber Source on Organ Weight, Digesta pH, Specific Activities of Digestive Enzymes and Bacterial Activity in the Gastrointestinal Tract of Piglets**

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ABSTRACT : The aim of this study was to explore the effects of fiber sources on gut development and bacterial activity in the gastrointestinal tract of piglets. Eighteen crossbred (Duroc×Landrace×Yorkshire) barrows were fed a basal diet based on corn plus soybean meal or similar diets in which a portion of the corn and soybean was replaced by 5% wheat bran or 5% sugar beet pulp. The results indicate that pigs fed diets containing 5% wheat bran or 5% sugar beet pulp had lower liver weights than control pigs ($p<0.01$). The relative weight of the pancreas in pigs fed diets containing 5% sugar beet pulp was greater than that of control pigs or pigs fed diets containing 5% wheat bran ($p<0.05$). The pH of the ileal digesta of pigs fed the diet containing 5% wheat bran was higher than that of control pigs or pigs fed the diet containing 5% sugar beet pulp ($p<0.05$). The lipase activity in the distal jejunum, proximal, and distal ileum of pigs fed the control diet was higher than that of pigs fed the diets containing 5% wheat bran or 5% sugar beet pulp ($p<0.05$). The concentration of volatile fatty acids anterior to the caecum was greater for the pigs fed the diet containing 5% sugar beet pulp, while the concentration of volatile fatty acids posterior to the ileum was greater for the pigs fed the diet containing 5% wheat bran. This means that sugar beet pulp increased the bacterial fermentation pre-caecum, while wheat bran increased the bacterial fermentation post-ileum. The concentration of bacterial nitrogen and bacterial protein/total protein in ileal digesta of pigs fed the control diet was higher ($p<0.05$) than that of pigs fed the diets contained either fiber source. Bacterial protein/total protein in the feces of pigs fed the diet containing 5% sugar beet pulp was higher than that of pigs fed the control diet. This means that inclusion of 5% wheat bran or sugar beet pulp in diets influenced the development of the digestive tract of piglet. The mechanism by which dietary fiber reduced specific activity of lipase needs further consideration. Dietary fiber influenced the bacterial activity in the digestive tract of piglets, sugar beet pulp increased the fermentation in the upper gastrointestinal tract, and while wheat bran increased the fermentation in the lower gastrointestinal tract. (*Asian-Aust. J. Anim. Sci.* 2002, Vol 15, No. 10 : 1482-1488)

Key Words : Wheat Bran, Sugar Beet Pulp, Piglet, Gastrointestinal Tract Development, Bacterial Activity

INTRODUCTION

The role of high-fiber ingredients in piglet diets has been explored very little, partly because the microflora are thought to be of minor importance in young pigs (Mosenthin et al., 1999). Recent interest in fiber has resulted from the possibility that fiber is involved in the prevention of some diseases (such as post-weaning diarrhea) and has possible health-modulating effects in the digestive tract (Mosenthin et al., 1999).

The present work was undertaken to study the influence of fiber source on piglet gastrointestinal tract development (using organ size, gastric and intestinal pH as well as specific activities of intestinal digestive enzymes as indicators) and bacterial activity in the gastrointestinal tract (using volatile fatty acid concentration and bacterial

nitrogen as indicators).

The physiological effect of individual dietary fiber is dependent on the monomeric residues present and the nature of linkages between these residues. The main monomeric residues in wheat bran are xylose and arabinose, while in sugar beet pulp it is uronic acid: soluble non-cellulose NSP (non-starch polysaccharide), insoluble non-cellulose NSP, cellulose, total NSP and lignin content (g/kg dry matter) of wheat bran and sugar beet pulp are: 29, 273, 72, 374, 75; 407, 177, 195, 779, 35 (Bach Knudsen, 1997). So, we select wheat bran as a source of insoluble dietary fiber and sugar beet pulp as a source of soluble dietary fiber.

MATERIALS AND METHODS

Animals and diets

Eighteen crossbred (Duroc×Landrace×Yorkshire) barrows, with an average body weight of 11.08 ± 0.57 kg, were allotted to three treatments on the basis of weight and litter. Piglets were housed in steel metabolism cages and fed a basal diet based on corn plus soybean meal or similar diets in which a portion of the corn and soybean was replaced by 5% wheat bran or 5% sugar beet pulp

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(Table 1). The experimental diets were pelleted using a flat die pelleter with the exit temperature of the pelleter set at 48.5°C.

Chemical analyses for diet

Protein (Nitrogen \times 6.25) was determined in a Kjell-Foss 1620 auto analyser (Foss Electric A/S) by the Kjeldahl method. The gross energy content was measured with an adiabatic bomb calorimeter. Calcium, total phosphorus, neutral detergent fiber and acid detergent fiber were determined according to the methods of the Association of Official Analytical Chemists (AOAC 1990). Amino acids were determined using an amino acid analyzer (Hitachi L-8800, Japan) according to the method described by Li et al. (1994) following hydrolysis for 24 h in 6 N HCl.

Feeding management

The piglets were fed twice daily at 08:00 h and 16:00 h with total feed intake set at about 5% of body weight. Water

was present in the feed trough at other times. The temperature of the pig house was 14-18°C and the relative humidity was set at 40%-55%.

Sample taking

After 28 days of feeding, the piglets were slaughtered to take samples for analysis. Parameters recorded including the fill weight of the gastrointestinal tract as well as the empty weight of stomach, small intestine, large intestine, liver and pancreatic gland.

Piglets were fasted for 12 h, weighed and then killed with an i.v. injection of about 1.5 ml of a solution containing 250 mg embutramide and 8 mg tetracainehydrochloride. Following the removal of the gastrointestinal tract from the abdominal cavity, the tract was immediately separated by ligature into seven sections: the stomach; the duodenum; the jejunum (three equal sections); the ileum (two equal sections); the caecum; the proximal colon and the distal colon. The digesta from the each section was mixed and two sample of digesta were collected, one for the determination of the specific activity of digestive enzymes, and the other for the determination of volatile fatty acid concentration. These two samples were placed in a plastic tube that was then put into a portable ice-box. In less than an hour, the tube was moved to a -65°C freezer. The remaining digesta was used to measure the pH of digesta of stomach, jejunum, ileum, caecum, proximal colon and distal colon using a pH meter (Cole Parmer, model 59003-05).

Analytical methods and procedure for enzymes

Digesta was put into the centrifugal tubes, adding 5-10 times the volume of cooled ultrapure water, mixed to uniformity and then centrifuged (10,000 \times g, 4°C) for 15 min (Heraeus Sepatech, Biofuge 22 R). The supernatant was split into 5 sample tubes, and stored in a -65°C refrigerator until the determination of specific activities of digestive enzymes.

The activity of digestive enzymes and total protein were measured by the method described by Leng Peschlow (1989). The analyses were done using a Technicon RA1000 system (Bayer, USA). The specific activity of enzyme is equal to the activity of enzyme divided by total protein.

Analytical methods and procedure for VFA determination

Volatile fatty acids were measured by a modification of the capillary GC method described by Jensen et al. (1995). The configuration of the gas chromatograph (HP 6890 series) was as follows: HP-INNOWax (Mixed linked PEF) capillary columns 30 m \times 0.25 mm \times 0.2 μ m (HP No. 19091N-133). Carrier gas was nitrogen with a constant flow rate of 37 cm/sec, 1.8 ml/min. The column temperature was

Table 1. The composition of the experimental diets

	Control	Wheat bran	Sugar beet pulp
Ingredient (% as fed)			
Corn	55.25	51.80	50.87
Soybean meal	27.50	26.00	27.00
Wheat bran	-	5.00	-
Sugar beet pulp	-	-	5.00
Fish meal	6.00	6.00	6.00
Dried whey	5.00	5.00	5.00
Soybean oil	2.00	2.00	2.00
Dicalcium phosphate	0.95	0.85	1.05
Limestone	0.80	0.85	0.58
Iodized salt	0.20	0.20	0.20
L-lysine chloride	0.20	0.20	0.20
DL-Methionine	0.06	0.06	0.06
L-Threonine	0.04	0.04	0.04
Vitamin-mineral premix ¹	1.50	1.50	1.50
Chromium oxide	0.50	0.50	0.50
Chemical composition (% as fed)			
Crude protein (%)	19.91	20.37	20.52
Calcium (%)	0.89	0.89	0.90
Total phosphorous (%)	0.70	0.70	0.71
Lysine (%)	1.32	1.30	1.32
Threonine (%)	0.89	0.88	0.89
Neutral detergent fiber (%)	8.96	10.54	10.59
Acid detergent fiber (%)	4.13	4.54	5.18

¹ Premix provided the following per kg of diet: tylosin 40 mg; vitamin A, 5,512 IU; vitamin D₃, 551 IU; vitamin E, 100 mg; vitamin K₃, 2.2 mg; vitamin B₁₂, 27.6 μ g; riboflavin, 5.5 mg; D-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline chloride, 900 mg; Mn 100 mg; Fe, 100 mg; Zn, 100 mg; Cu, 250 mg; I, 0.3 mg; Se, 0.3 mg. All chemical compositions were chemically analyzed conducted in duplicate.

from 120°C for 11 min then increasing by 50°C/min to reach 250°C for 1 min. The inlet temperature was 185°C and the detector temperature was 210°C. The split ratio was set at 35:1 and the inlet volume was 2 µl.

Analysis procedure for bacterial protein

Bacterial nitrogen in ileal digesta and feces was analyzed using the procedure of Dierick et al. (1990) with some modifications. Exactly 0.6 g (± 0.0001 g) of air-dried sample was mixed with 30 ml cooled physiological saline solution and centrifuged (10,000 \times g, 4°C) for 30 min. The supernatant was discarded and the residue was washed in 30 ml 2% sodium dodecyl sulfate detergent (100°C) and centrifuged (10,000 \times g, 4°C) for 30 min. The supernatant was transferred to a tube and its total protein (bacterial protein) content determined.

Statistical analysis

One way ANOVA (SPSS6.0 for Windows) was done with the dietary treatment as the main factor. If the difference was significant, then Duncan's multiple range test was used for post hoc multiple comparison. For all parameters the individual pig was the experimental unit.

RESULTS AND DISCUSSION

Organ weight

The health of the pigs was good throughout the study. Pigs fed diets containing 5% wheat bran or 5% sugar beet pulp had lower liver weights than the control pigs (Table 2, $p < 0.01$). There was also a tendency for a decreased pancreas weight in response to fiber inclusion ($p = 0.092$). The relative weight of the pancreas in pigs fed diets containing 5% sugar beet pulp was greater than that of control pigs or pigs fed the diets containing 5%

wheat bran ($p < 0.05$).

Previous studies have shown an increase in the weights of the visceral organ in response to the inclusion of dietary fiber in the diets of growing pigs (Pond et al., 1988; Jorgensen et al., 1996) and piglets (Hambrecht, 1998), whereas Jin et al. (1994) failed to show this effect. Both Jin et al. (1994) and Hambrecht (1998) exposed piglets over a period of 14 days to high-fiber diets before the measurements were taken. Thus, it can be questioned if the time period was too short to measure the stimulatory effects of dietary fiber on visceral weights as was suggested by Jin et al. (1994). Hambrecht (1998) assumed that the lack of response to dietary fiber was due to a low production rate of volatile fatty acids due to the fact that a slow and poorly fermentable fiber source was used. Alternatively a relatively high baseline concentration of volatile fatty acids could also be the cause of the poor response. The nature of these increases in weight and their biological significance have not been determined but it is assumed that prolonged intakes by pigs of diets containing high levels of fiber may lead to a hypertrophy and hence increase weight of segments of the gastrointestinal tract (Stanogias and Pearce, 1985).

Specific activities of digestive enzymes

The activity of lipase in the distal jejunum, proximal, distal ileum of the pigs fed the control diet was higher than that of pigs fed the diets containing 5% wheat bran or 5% sugar beet pulp (Table 3, $p < 0.05$).

Previous studies about the inclusion of fiber components on the activities of digestive enzymes in the gastrointestinal tract are in disagreement. Mosenthin and Sauer (1993) reported that the inclusion of pectin (7.5%) in finishing barrows diets did not affect the flow of pancreatic juice and the total secretion of nitrogen, lipase, trypsin and chymotrypsin. However, there was a significant decrease in

Table 2. Effects of dietary fiber source on organ weights of piglets

Treatment	Control	Wheat bran	Sugar beet pulp	SEM	P
Average live body weight (kg)	24.4	20.8	21.7	2.65	0.89
Stomach weight (g)	182.7	176.7	180.0	10.40	0.78
Relative weight (%)	0.8	0.9	0.8	0.06	0.13
Small intestine weight (g)	1,108.7	1,184.0	1,014.7	153.03	0.42
Relative weight (%)	4.5	5.7	4.7	0.74	0.14
Large intestine weight (g)	490.7	521.7	448.0	59.63	0.34
Relative weight (%)	2.0	2.5	2.1	0.31	0.12
Digesta weight (g)	3,362.8	2,820.7	3,669.5	723.20	0.37
Relative weight (%)	14.0	13.4	16.4	2.66	0.37
Liver weight (g)	778.0 ^a	656.7 ^b	634.0 ^b	39.91	0.01
Relative weight (%)	3.2	3.2	2.9	0.20	0.16
Pancreases weight (g)	54.7	44.6	54.0	5.78	0.09
Relative weight (%)	0.2 ^b	0.2 ^b	0.3 ^a	0.01	0.02

^{a,b} Means in the same row with different superscript differ ($p < 0.05$).

Relative weight=absolute weight /live body weight.

Table 3. Effects of dietary fiber source on specific activity of digestive enzyme of piglets

Treatment	Control	Wheat bran	Sugar beet pulp	SEM	P
Proximal jejunum					
Lipase (1,000 U/g protein)	6.6	4.0	5.5	3.87	0.85
Amylase (1,000 U/g protein)	40.4	61.1	31.2	29.34	0.68
Proteinase (100 U/g protein)	4.4	6.1	5.0	2.17	0.81
Middle jejunum					
Lipase (1,000 U/g protein)	4.9	26.0	4.4	20.38	0.63
Amylase (1,000 U/g protein)	24.8	81.0	37.0	38.22	0.50
Proteinase (100 U/g protein)	3.2	10.5	6.7	6.55	0.70
Distal jejunum					
Lipase (1,000 U/g protein)	17.7 ^a	2.5 ^b	3.9 ^f	1.14	0.03
Amylase (1,000 U/g protein)	73.8	73.9	44.2	44.37	0.88
Proteinase (100 U/g protein)	7.8	8.1	6.6	4.54	0.97
Proximal ileum					
Lipase (1,000 U/g protein)	22.7 ^a	2.7 ^b	4.0 ^f	5.46	0.06
Amylase (1,000 U/g protein)	94.2	47.3	36.7	34.22	0.36
Proteinase (100 U/g protein)	9.0	5.4	4.8	2.11	0.25
Distal ileum					
Lipase (1,000 U/g protein)	7.8 ^a	2.1 ^b	2.9 ^f	1.50	0.02
Amylase (1,000 U/g protein)	48.9	28.1	55.3	28.54	0.59
Proteinase (100 U/g protein)	6.4	4.6	6.6	3.40	0.79

^{ab} Means in the same row with different superscript differ ($p < 0.05$).

the secretion of α -amylase. Dunaif and Schneeman (1981), using an *in vitro* method, found that insoluble dietary fiber decreased the activity of amylase, lipase, trypsin and chymotrypsin. Pectin, a soluble dietary fiber source, had no effects on trypsin activity, while it improved the activity of amylase, lipase and chymotrypsin. Calvert et al. (1985) pointed out that an addition of 10% insoluble fiber derivatives (cellulose or alfalfa), or 5% soluble viscous fiber (pectin, guar gum, or metamucil) to a fiber-free diet did not affect the activity of amylase, lipase, trypsin, and chymotrypsin in the pancreatic gland of rats. Hansen (1987) indicated that both wheat bran and pectin exerted inhibitory actions on pancreatic lipase activity measured in buffer solutions and in human duodenal juice. Hendrick et al. (1992) indicated that red wheat bran, white wheat bran and sugar beet fiber inhibited lipase-catalyzed hydrolysis of tributyrin *in vitro*. Leng Peschlow (1989) reported that wheat bran increased lipase, maltase and lactase activity and inhibited α -amylase activity. Pectin and xylan decreased lipase and pepsin activity and increased chymotrypsin activity but had opposite effects on maltase activity. Alfalfa was able to stimulate lactase and lipase activity but depressed trypsin and α -amylase activity. The inactivation of enzymes by dietary fiber can at least partly be explained by adsorption to the fiber or by the presence of enzyme inhibitors especially in natural compounds. In fact, the fraction of bran that can be solubilized in the aqueous phase induced this reduction in porcine pancreatic lipase activity (Lairon et al., 1985). The reasons for activation processes are unknown.

VFA concentration in the gastrointestinal tract

The concentration of acetic acid, valeric acid and total VFA in the stomach of pigs (Table 4) fed the diet containing 5% sugar beet pulp was higher than that of pigs fed the control diet or the diet containing 5% wheat bran ($p < 0.05$). The concentration of propionic acid in the stomach of pigs fed the diet containing 5% sugar beet pulp was higher than that of pigs fed the control diet ($p < 0.05$). The concentration of propionic acid in the jejunum of pigs fed the diet containing 5% sugar beet pulp was higher than that of pigs fed the control diet or the diet containing 5% wheat bran ($p < 0.05$). The concentration of acetic acid, propionic acid and total VFA ($p < 0.05$) in the ileum of pigs fed the diet containing 5% sugar beet pulp was higher than that of pigs fed the control diet or the diet containing 5% wheat bran. The concentration of acetic acid, propionic acid, butyric acid and total VFA ($p < 0.05$) in the caecum of pigs fed the diet containing 5% wheat bran was higher than that of the control pig fed or the pigs fed the diet containing 5% sugar beet pulp. The concentration of propionic acid and total VFA ($p < 0.05$) in the proximal colon of pigs fed the diet containing 5% wheat bran was higher than that of pigs fed the control diet or the diet containing 5% sugar beet pulp. The concentration of acetic acid and total VFA ($p < 0.05$) in the distal colon of pigs fed the diet containing 5% wheat bran was higher than that of pigs fed the control diet or the diet containing 5% sugar beet pulp. The concentration of valeric acid in the distal colon of pigs fed the control diet was higher than that of pigs fed the diet containing 5% sugar beet pulp ($p < 0.05$). This

Table 4. Effects of dietary fiber source on the concentration of volatile fatty acids (VFA) in gastrointestinal tract of piglets (mg/L)

Treatment	Control	Wheat bran	Sugar beet pulp	SEM	P
Stomach					
Acetic acid	675.2 ^b	700.7 ^b	919.9 ^a	70.41	0.05
Propionic acid	114.1 ^b	136.9 ^{ab}	182.9 ^a	13.74	0.05
Valeric acid	42.3 ^b	26.6 ^b	119.4 ^a	24.80	0.01
Total VFA	831.5 ^b	864.3 ^b	1,381.5 ^a	121.89	0.02
Jejunum					
Acetic acid	793.8	788.6	802.5	42.18	0.92
Propionic acid	138.7 ^b	135.0 ^b	146.6 ^a	2.07	0.01
Valeric acid	25.1	31.6	32.3	4.91	0.28
Total VFA	957.6	984.8	981.4	45.64	0.62
Ileum					
Acetic acid	903.4 ^b	1,008.4 ^{ab}	1,577.6 ^a	149.04	0.07
Propionic acid	145.9 ^b	161.9 ^b	298.8 ^a	37.48	0.06
Valeric acid	54.9	45.9	43.6	17.48	0.71
Total VFA	1,104.2 ^b	1,216.3 ^{ab}	1,920.0 ^a	227.54	0.07
Caecum					
Acetic acid	4,051.3 ^{ab}	5,039.4 ^a	3,524.1 ^b	501.61	0.03
Propionic acid	1,402.3 ^b	1,972.8 ^a	1,331.3 ^b	185.05	0.02
Butyric acid	599.6 ^b	836.9 ^a	562.8 ^b	75.87	0.04
Valeric acid	315.5	393.9	270.7	167.13	0.67
Total VFA	6,419.9 ^b	8,271.3 ^a	5,713.4 ^b	587.01	0.02
Proximal colon					
Acetic acid	3,921.3	4,767.7	3,851.2	603.12	0.15
Propionic acid	1,564.6 ^b	2,017.5 ^a	1,511.8 ^b	137.20	0.02
Butyric acid	675.9	903.5	720.4	135.53	0.13
Valeric acid	344.3	403.3	297.3	142.04	0.67
Total VFA	6,590.7 ^b	8,141.4 ^a	6,420.4 ^b	473.42	0.05
Distal colon					
Acetic acid	3,231.0 ^{ab}	3,688.1 ^a	2,989.7 ^b	216.02	0.09
Propionic acid	2,037.3	1,945.2	1,544.1	314.07	0.16
Butyric acid	691.0	853.5	682.3	185.11	0.46
Isobutyric acid	185.6	236.9	143.5	128.31	0.73
Valeric acid	386.4 ^a	319.8 ^{ab}	206.7 ^b	54.13	0.01
Total VFA	6,579.9 ^{ab}	7,125.0 ^a	5,542.3 ^b	509.64	0.10

^{ab} Means in the same row with different superscript differ ($p < 0.05$). In some samples, some volatile fatty acids were undetectable in some segments (such as Butyric acid and Isobutyric acid in stomach) of the gastrointestinal tract, so they were not shown in this table, but they are included in calculating total volatile fatty acids.

means that sugar beet pulp increased the bacterial fermentation pre-caecum, while wheat bran increased the bacterial fermentation post-ileum. These results are similar with the literature reported, as Bardon and Fioramonti (1983) found that the addition of bran (100 g/d) to a basal milk diet (20 g/kg body weight per day), increased the daily fecal excretion of VFA by 167%. Stanogias and Pearce (1985) pointed out that the concentration of total VFA in the proximal colon increased with increasing levels of neutral detergent fiber (NDF), and this increase was highly dependent on the source of NDF in the diet. Sauer et al. (1991) found that the isovaleric acid concentration (0.105 mmol/L) in the ileal digesta of pigs fed diets containing wheat straw was significantly higher than that of pigs fed diets containing cellulose (0.038 mmol/L, $p < 0.05$). Michel and Rerat (1998) indicated that the amount of volatile fatty acids appearing in the portal

blood of pigs was higher ($p < 0.001$) after ingestion of a sugar beet fiber-rich diet (10%) than after that of a wheat bran-rich diet (10%).

Digesta pH

The pH of the ileal content of pigs fed the diets containing 5% wheat bran (Table 5) was higher than that of the control pigs or pigs fed diets containing 5% sugar beet pulp ($p < 0.05$). In general, sugar beet pulp tended to decrease pH in all segments of the gastrointestinal tract relative to wheat bran. We know that VFA are acidic, so the more VFA produced, the lower the pH. So the discussion above can at least partly explain these results. Drochner (1991) found that the inclusion of 6% crude fiber decreased the stomach pH of pigs. Van der Meullen and Bakker (1991), using 18 crossbred (Duroc × Landrace) growing-finishing pigs, studied the effects of fiber source on the

Table 5. Effects of dietary fiber source on the pH of gastrointestinal tract in piglets

Treatment	Control	Wheat bran	Sugar beet pulp	SEM	P
Stomach	3.3	3.6	3.4	0.86	0.90
Jejunum	6.1 ^b	6.8 ^a	5.9 ^b	0.21	0.03
Ileum	7.4	7.4	7.0	0.39	0.36
Caecum	6.3	6.3	5.8	0.37	0.23
Proximal colon	6.1	6.4	6.1	0.40	0.55
Distal colon	6.8	7.1	6.7	0.33	0.45

^{ab} Means in the same row with different superscript differ ($p < 0.05$).

physicochemical parameters of the stomach and small intestine contents using a basal diet containing 7.9% NDF. Five high-fiber diets were fed with a level of 20.0% for wheat bran, sunflower hulls, sugar beet pulp, soybean hulls or pea hulls. The results indicated that the stomach pH of pigs fed diets containing 20% sugar beet pulp was lower than that of control pigs. Johansen (1993) reported increasing the dietary fiber level had no effects on stomach pH, whereas Jensen and Jørgensen (1994) found the stomach pH was increased as fiber content increased.

Bacterial nitrogen

Bacterial nitrogen concentration (% of dry matter or % of total nitrogen) in the ileal digesta of pigs fed the control diets was significantly higher than that of the WB or WBP group (Table 6, $p < 0.05$). This indicates a greater bacterial anabolism in the upper digestive tract of the control pigs than of the fiber treatment pigs. The reason may be that fiber restrains the anabolism of bacterial, or the bacterial in the upper gastrointestinal tract may prefer a more readily fermentable substrate, such as starch, sugar, protein, peptide or amino acids. In Table 1, the main difference among the dietary treatments was the source and amount of dietary fiber. As the feed intake was the same among pigs, the pigs fed diets containing the fibrous feedstuffs had less easily fermentable carbohydrate for the bacterial to degrade, which reduced the anabolism of bacterial, and resulted in less bacterial protein concentration in the ileal contents.

The substrate that was not digested in the upper gastrointestinal tract by enzymes or bacteria, entered into the large intestine, where it was degraded predominantly by bacteria. As stated previously, fiber was digested less in the upper gastrointestinal tract, and more substrate will

consequently be available for fermentation in the large intestine, which resulted in more bacterial protein in the feces.

Bacterial nitrogen content is dependent on type and composition of diet, the bacterial nitrogen content was lower when purified or semi-purified diets were fed than when grain-based diets were fed (Mosenthin, 1987). Inclusion of guar flour or cellulose to the rat diets caused the rise of bacterial nitrogen excretion. (Muller and Harmuth Hoene, 1984; 1986). Sauer et al. (1991), using 10% Alphafloc or barley straw to substitute corn starch of a basal diet, indicated that the bacterial nitrogen (using 2,6 diaminoipimetic acid (DAPA) as an indicator) content in the feces of pigs fed diets containing either 10% Alphafloc or barley straw was significantly lower than that of control pigs (17.02 and 19.24 vs 33.75 mg/kg feces DM, respectively $p < 0.05$), while either fiber increased bacterial nitrogen excretion (1.83 and 2.42 vs 2.90 respectively, mg/kg DM intake $p < 0.05$). Schulze et al. (1995) substituted glucose with different levels (0%, 6%, 12%, 18%) of purified NDF from wheat bran to study the influence of NDF on bacterial nitrogen (using DAPA as an indicator) in ileal digesta. The results indicated that bacterial flow in the ileum was variable (1.830, 2.037, 1.827, 2.215 g/d for the four treatments respectively). The percentage of bacterial nitrogen in total nitrogen was decreased as the NDF content increased (0.665, 0.647, 0.514, 0.544 respectively), but there were no differences among dietary treatment ($p > 0.05$).

The neutral detergent fiber or acid detergent fiber contents of diets among treatments do not show significant difference (Table 1), while the results indicated that there are differences in gastrointestinal development and bacterial activity in the gut of piglets. Therefore, a more appropriate parameter to indicate dietary fiber, especially in nutrition research, need further research.

IMPLICATIONS

This study shows that inclusion of 5% wheat bran or sugar beet pulp in piglet diets influences organ weight, pH of jejunum and the specific activity of lipase. Therefore the development of the digestive tract can be modulated by the use of different sources and levels of dietary fiber. The mechanism by which wheat bran or sugar beet pulp bring

Table 6. Effects of dietary fiber source on microbial protein concentration in ileal digesta and feces of piglets (%)

Treatment	Control	Wheat bran	Sugar beet pulp	SEM	P
Ileal digesta					
Microbial protein content	4.1 ^a	3.4 ^b	3.3 ^b	0.23	0.01
Microbial protein/total protein	26.0 ^a	23.4 ^b	22.5 ^b	0.82	0.02
Feces					
Microbial protein content	6.1	6.4	6.7	0.82	0.38
Microbial protein/total protein	33.4 ^b	36.6 ^{ab}	37.7 ^a	1.36	0.03

^{ab} Means in the same row with different superscript differ ($p < 0.05$).

reduced activity of lipase needs further consideration. Dietary fiber influences the bacterial activity in the digestive tract of piglets. Sugar beet pulp increases the fermentation in the upper gastrointestinal tract, and while wheat bran increases the fermentation in the lower gastrointestinal tract. Both dietary fiber sources result in higher bacterial nitrogen content in the feces.

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